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Smuts of Cereal and Forage Crops in Kansas and Their Control

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SUMMARY—CEREAL AND FORAGE CROP SMUTS

NAME OF DISEASE	Group*	Occurrence and location of the organism	Control measures
Corn smut	1	Spores in the soil from smutted refuse	No practical method of control. Seed treatment will not prevent corn smut. Do not plant corn on the same land more often than once in 4 years. (Pp. 9 and 11.) Some hybrids are said to be more susceptible than others. (Pp. 9 and 12.)
Head smut of sorghum	1	Spores in the soil	Seed treatment does not control the disease. Remove and burn diseased plants. Rotate crops. Plant resistant varieties. (Pp. 9 and 13.)
Flag smut of wheat	1	Spores in the soil and on seed	Rotate crops. Treat seed. Grow resistant varieties. (Pp. 7, 9 and 20.)
Kernel smut of sorghum	2	Spores lodged on the outside of the seed	Chemical dust treatments. (Pages 13, 31 and 32.)
Smut of oats	2	Infection lodged on or between the glumes of the seed	(1) Chemical dust treatment. (Pages 31, 33.) (2) Formaldehyde treatment: 1 pint to 10 gallons of water; sprinkle seed and allow to stand for 5 hours or over night. (Page 33.) Formaldehyde spray method may be used in place of the sprinkling method. (Page 33.) (3) Grow an adapted resistant variety. (Pages 6 and 25.)
Stinking smut or bunt of wheat	2	Spores lodged on the outside of the seed	(1) Chemical dust treatments, copper carbonate, New Improved Ceresan. (Page 31.) (2) Grow an adapted, resistant variety. (Pages 6, 25.)
Kernel smut of millet	2	Spores lodged on the outside of the seed	Chemical dust treatment. (Page 31.)
Covered smut of barley	2	Infection lodged on or between the glumes of the seed	(1) Use seed that has been cleaned. (2) Chemical dust treatment. (Page 31.)
Black loose smut of barley	2	Infection lodged on or between the glumes of the seed	Chemical dust treatment. (Page 31.)
Loose smut of wheat	3	The infection *inside* the seed itself	Use adapted, resistant varieties. (Pages 6, 25.) See modified hot-water treatment in connection with seed plots. (Page 33.)
Brown loose smut of barley	3	The infection *inside* the seed itself	See modified hot-water treatment in connection with seed plots for spring or winter varieties. (Page 33.)

* According to their life history, cereal smuts may be placed into one of three groups according to the occurrence and location of the organism causing the disease.

SMUTS OF CEREAL AND FORAGE CROPS IN KANSAS AND THEIR CONTROL[1]

L. E. Melchers

LOSSES FROM SMUT DISEASES

The smuts of wheat, oats, barley, corn, sorghum, and millet are known to most Kansas farmers, since these diseases occur in all parts of Kansas where these crops are grown. They are widespread and destructive. Millions of bushels of grain are lost annually from these diseases. Much of this loss can be prevented by applying inexpensive remedial measures.

The approximate loss from smut in a field is not difficult to estimate. Ordinarily, except in the case of corn, a smutted plant does not produce seed or grain. The percentage of smut may be determined by counting the number of smutted plants and healthy plants in a given area. The loss in bushels or dollars may be roughly estimated by calculating what the yield or value of the crop would have been if the smut had not been present.

It is not generally known that farmers in Kansas probably lose more from grain smut diseases than from diseases of livestock. It is impossible to give accurate figures on annual loss in dollars from livestock diseases, and it is therefore unsatisfactory to attempt to make a direct comparison between plant and animal disease losses. Losses from smuts vary from year to year just as do those from livestock diseases.

Records show that the loss from cereal smuts in Kansas is declining steadily despite the fact that acreages of cereals are increasing. This is explained by (1) farmers' appreciation of the importance of prevention, (2) improved chemical methods for control, and (3) a concerted effort during the past 15 years to produce improved smut-resistant varieties of cereals and release of these varieties by the Kansas Agricultural Experiment Station.

Plant diseases frequently appear in epidemics, as the figures given in Table 1 on the losses from smuts in Kansas cereal crops will show. Most of these losses could have been prevented by proper control measures.

Losses from the other plant diseases attacking these crops, as the stem rust, leaf rust, foot-rot, etc., are not included here; if they were, the figures would be greatly increased. Although farmers often are more impressed by the loss of livestock from disease than by the loss from plant diseases, the latter is important and can be greatly reduced by simple treatments.

The loss from the bunt, or stinking smut, of wheat varies greatly. Fields in Kansas have been observed to have as high as eighty-five

1. Contribution No. 475, serial No. 391, Department of Botany.

percent smut. Some commonly grown varieties, Red Chief, Chiefkan, and Tenmarq, are very susceptible to stinking smut; others more recently introduced, such as Comanche, are highly resistant, having been bred specifically for that characteristic. The growing of Comanche on large acreages will do much to reduce the loss in Kansas from bunt. Pawnee, although not so resistant to bunt as Comanche, is more resistant than any variety hitherto commonly grown in Kansas.

The loose smut of wheat, although not so abundant in Kansas, is by no means uncommon. It has been increasing for the past twenty years. Nearly every field has one percent or less, and frequently fields are examined that have from five to fifteen percent. Distinct progress has been made in breeding loose smut-resistant varieties of hard winter wheat adapted to Kansas. Kawvale and Pawnee are both highly resistant to loose smut. Growing resistant varieties will largely eliminate the loss from this disease. There is no satisfactory seed treatment for loose smut control. This is the main reason why the disease has been so widely spread in the Kansas wheat crop.

TABLE 1.—Estimated loss from smut diseases in cereals in Kansas

DISEASE	Year	Percent of crop loss	Loss in dollars
Wheat stinking smut (bunt)	1924	4	6,845,000
	1925	6	6,630,000
	1926	10	19,993,000
Oat smuts	1930	6	848,000
	1933	6	519,000
	1936	20	4,143,000
Sorghum kernel smut	1926	10	3,241,000
	1940	3	785,000
	1944	6	4,219,000

Oat smut is always present in Kansas when fields are planted with untreated seed. Fields planted with untreated seed may have as high as forty percent smut. In 1936 there occurred the most destructive outbreak of oat smut in the history of Kansas agriculture. Occasional fields had as high as ninety-five percent loss from smut, and many others were too smutty to be harvested for grain. Where seed disinfection is properly practiced, the loss from oat smut is negligible. Breeding of the resistant oat varieties Neosho, Osage, Cherokee, and Nemaha is an advance in Kansas agriculture. It required about twelve years to achieve this goal. Because of the many problems involved in obtaining a smut-resistant variety of oats adapted to Kansas, the performance of these varieties will be watched with interest. It is believed that the loss from oat smut will steadily become less in Kansas.

Barley smuts are always present and are difficult to distinguish. In certain varieties, such as Flynn, the smut has become a serious problem. Control of the brown loose smut is difficult because a special hot-water treatment is required. Many barley fields have from one to four percent of the various smuts, and occasionally fields are found to contain ten to fifty percent. The barley smuts are found in most fields planted with untreated seed. In 1936 barley smuts were unusually common and heavy losses occurred, particularly in fields of winter barley. Winter and spring barley varieties are subject to the same smut diseases. The acreage of winter barley has increased in Kansas in the past six years, and as a result the barley smuts have become conspicuous.

Flag smut of wheat is almost a thing of the past in Kansas. It is a disease, however, of serious consequences in some areas of the United States and other wheat-growing countries. It occurs to a slight extent in northeastern Kansas where soft wheats are grown. Fortunately, such varieties as Kawvale and Clarkan and some other varieties commonly grown in the soft wheat area which have replaced Harvest Queen, Fulcaster, Fultz, Currell, etc., are not susceptible. The hard winter wheat varieties commonly grown in central and western Kansas are highly resistant. Here is another instance in which resistant or immune varieties have provided control of a dangerous smut disease.

Millet, although not extensively grown in Kansas, has a smut disease that at times becomes troublesome. Farmers have reported from one to twenty-five percent of their millet crop destroyed by smut.

There are two smut diseases attacking the sorghum crop in Kansas, the covered kernel smut and the head smut. Fields are found each year that contain from a trace to seventy-five percent kernel smut. The kernel smut, which is the most common and destructive, is a disease which can be completely and easily controlled by seed treatment.

The less-common head smut is only occasionally found and then usually in varieties of sorgo such as Red Amber, Freed, and Sumac. This disease is not widespread in its attack on the sorghum crop of Kansas. It does not seem likely that head smut will become a troublesome disease, for it has been known in the state for fifty years and it does not appear to be increasing.

Broomcorn is affected to some degree by both of these sorghum smuts. The greatest damage to this crop is from the kernel smut, which has the singular effect of not only destroying the seed but also injuring the brush, discoloring it and causing a central, thickened stem to appear in the heads. This produces a brush of inferior quality. It is not uncommon to find from five to ten percent of the broomcorn plants attacked.

Corn smut is found abundantly in every cornfield in Kansas. In fact, it occurs wherever maize is grown in the United States. It is common and destructive to all varieties of field, pop, and sweet

corn. The actual loss in a field cannot be determined with any degree of accuracy. Since the smut may attack various parts of a plant other than the ear, the extent of injury may only be approximated. It is believed, however, that a badly smutted plant has its yielding capacity reduced by one third.

From five to eighty percent of the plants in a field may show smut. As with the other smut diseases, corn smut is worse some years than others. It is safe to say that several million bushels of corn are lost each year in Kansas from corn smut.

There is a smut disease attacking rye, but this crop is not extensively grown in Kansas and the smut has only rarely been observed.

CAUSE OF THE SMUT DISEASES

Smut diseases are caused by minute parasitic plants known as fungi and not, as sometimes believed, by hot, muggy weather, "sour sap," or the time at which the crop is planted. While it is true that weather conditions (temperature and moisture) frequently determine the amount of diseases that occur, these factors are not the cause. It requires the spores or "germs" of fungi to cause infection. The environment is either favorable or unfavorable for the infecting parasite. As a rule these fungi infect either by entering the young floral parts or by gaining entrance to the plant in the seedling stage and developing within the tissues of their hosts. As long as the fungus remains within the tissues there is nothing externally visible by which its presence can be detected; hence, it is not easy to determine from outside appearance whether a plant in its early stage of development is infected. When the fruiting stage is reached, the diseased plants can be readily detected. As the infected plants begin to form seed, the diseased parts are transformed into a dark powdery dust. This is characteristic of the smut fungus. The dust is composed of an infinite number of microscopic, reproductive bodies of the fungus, known as "spores." These perpetuate and propagate the disease from year to year, either by clinging to the outside of the seed and hulls when a crop is threshed, by infecting the interior of the developing seed during the flowering period, or by infecting the regions of the glumes. In some cases the spores remain alive in the soil from year to year.

The various smut diseases of plants are caused by different kinds or species of smuts. They affect the cereals and other plants in various ways, but each different smut disease is produced by a specific fungus. For example, the spores of the stinking smut of wheat cannot produce the loose smut of wheat, the smuts of barley, or corn smut. A given smut fungus will cause only its own specific disease. Wheat seed might be contaminated with oat smut spores, but the wheat smut disease would not result. If a badly smutted crop of wheat is grown in a certain field, there is no danger in planting oats on the field the following year, as oat smut would not result from such a practice.

A number of Kansas crops which are quite distinct from the farmer's point of view are botanically closely related. These comprise the general group known as the sorghums, and include kafir, feterita, broomcorn, milo, Sudan grass, and the sorgos (cane). The kinds of smut attacking kafir also occur on all the other susceptible sorghums.

THREE GROUPS OF SMUT

Since there are nine important cereal and forage crop smut diseases in Kansas, it seems desirable to group them arbitrarily according to their life habits and methods of control. Smut diseases of cereals may be placed in one of three groups, based on their life cycles. (See Summary, p. 4.) These groups, with the smuts included therein, may be described as follows:

Group 1.—Corn Smut, Head Smut of the Sorghums, and Flag Smut of Wheat.—The smuts of this group cannot be prevented by treating the seed. The organisms which cause and perpetuate these diseases are not necessarily carried on the outside of the seed.

Infection results chiefly from the spores which live and winter over in the soil. There is, however, some difference between the life habits of corn smut, head smut of sorghum, and flag smut of wheat. As far as known, most of the infection of corn smut appears to be due to secondary spores resulting from germination of the overwintered spores in the soil. These are carried from the soil by the wind and alight on the young corn plants, causing local infection. Later a smut boil may develop wherever infection has occurred. The infection may be on the ear, tassel, leaf sheath, or node; in other words, a local infection.

In head smut of sorghum and flag smut of wheat, the fungus gets into the seedling directly from the soil and in that way alone causes infection. This is called a systemic infection. The spores which infect are not carried to the aerial parts of the plant, as in corn smut. Once inside the sorghum seedling or wheat plant, the fungus grows within the tissues and keeps pace with their development. In sorghum no evidence of disease is seen until the head emerges from the sheath, when instead of grain a smutted mass appears. In flag smut of wheat, the spore masses occur in long linear stripes or streaks in the leaf and leaf sheath when the plant is about half grown.

The spores producing all three of these diseases live over in the soil. It is always advisable, however, to disinfect the surfaces of sorghum and wheat seed so as to kill spores of smuts that may be present.

Group 2.—Kernel Smut of the Sorghums, Stinking Smut of Wheat, Smut of Oats, Covered Smut of Barley, Black Loose Smut of Barley, and Smut of Millet.—The smuts of this group have been thoroughly studied and it has been found that they can be controlled by seed treatments, since the spores of the fungi causing them cling to the seed.

The smut spores are scattered by the wind at harvest time, chiefly in threshing, and are further disseminated by means of contaminated machinery, sacks, or bins. If smutted seed is planted, the adhering smut spores germinate simultaneously with the sprouting seed. The fungus penetrates the tissues of the seedling, keeping pace with its growth until heading time approaches. Instead of normal kernels, a mass of smut or "smut balls" occurs in place of each kernel. The spores comprising these masses are scattered by various agencies, and cling to the outside of healthy seed. When this seed is planted, the same series of events is repeated.

In Kansas, the spores causing these different smut diseases do not live over in the soil. This group of smuts is, therefore, controlled by disinfecting the surface of the seed before planting, or by planting resistant varieties.

Group 3.—Loose Smut of Wheat and Brown Loose Smut of Barley.—These two smuts may be prevented by a special kind of hot-water treatment of the seed or by growing resistant varieties. The infection producing these diseases is found between the glumes and inside the seed; that is, *infection exists inside the embryo of the seed and in the hulls of the barley.*

When the heads emerge from the "boot" in wheat and barley, one may notice the first indications of loose smut. In place of seed formation, a loose, powdery mass of spores develops. All or most of the glumes and beards are absent, and the smut mass clings to the stem. These spore masses are soon scattered, leaving the naked stems of the heads remaining. The spores are carried to neighboring healthy plants, which may become infected if in full bloom. By alighting on the ovary of the flower of wheat or barley at just the right stage, they germinate, penetrate it, and infect the embryo of the growing seed. In barley, infection also takes place in the glumes. After infection has resulted, the fungus goes into a resting stage and remains quiescent. The infected seed, however, continues to grow, and develops into an outwardly normal-appearing kernel, although it is internally infected with the loose smut fungus. If this seed is planted the next year without special treatment, the plant developing therefrom will be affected with the loose smut, for the fungus is *inside* the embryo of the seed, and will grow inside the developing plant until it reaches maturity.

A table giving the common names and control measures for the various smuts occurring in Kansas is found in the Summary.

CHARACTERISTICS OF THE DIFFERENT CEREAL SMUTS

Corn Smut

Corn smut, *Ustilago zeae* (Beck.) Ung., is usually found on the tassel, ear, lower ear buds, or at the nodes of the plant (Fig. 1). Occasionally it will also be found on the stalk and leaves. This disease attacks field corn, popcorn, and sweet corn and is an important pest. In the early stages, the smut masses are white and covered

with a thin, grey membrane, which at certain stages has a silvery luster. (Fig. 1, A and D.) The smut mass becomes black as it matures and the surrounding membrane ruptures, releasing the black spores. These "smut boils" contain millions of spores which are scattered by the wind and rain. They fall to the soil and also are distributed over the corn fodder, which is fed to livestock. The spores withstand extremes of weather conditions, such as freezing and drying. The spores may live over for several years in the soil.

FIG. 1.—Corn smut on various parts of the plant.

It has been found that the spores lose their infective power, however, after passing through the alimentary canal of animals.

There is no satisfactory method of control for corn smut. If land is not planted to corn more often than once in every fourth year, the loss from smut appears to be less. The time of planting has no marked effect on the amount of corn smut that is obtained. No open-pollinated varieties or hybrids are resistant. It is hoped that some day resistant hybrids will be obtained. At present there are no such varieties available for Kansas, although it is claimed that certain hybrids are now more resistant than others. When sufficient information is available on smut resistance in corn hybrids, the grower will be informed. *Because of its life history corn smut cannot be controlled by any known seed treatment.*

Smuts of Sorghum

Up to 1891 the sorghum smuts were uncommon in Kansas, but since then they have been increasing steadily. Those who have grown kafir, cane, milo, Sudan grass, or broomcorn undoubtedly have seen sorghum smut.

There are two principal species or kinds of sorghum smut found in this state, namely, the head smut (Fig. 2) and the kernel smut (Fig. 3.) The latter is the more common and destructive.

A few years ago milos and feteritas were regarded as immune or highly resistant to sorghum smut; but in recent years, certain physiologic races of kernel smut have attacked most of the milos and certain milo hybrids such as Wheatland and Colby. Kafirs are especially susceptible to sorghum kernel smut as are also the sorgos. The only variety of sorghum in the breeding nursery that has remained immune over a long period of years is Spur feterita. It is hoped that crossing this variety with other sorghums will produce resistant grain and forage types adapted to Kansas.

Kernel smuts, *Sphacelotheca sorghi* (Lk.) Cl., and *Sphacelotheca cruenta* (Kühn) Potter,[2] are noticeable when the sorghums begin to head. Close examination shows that affected heads bear "false" kernels. These are composed of a mass of smut spores enclosed in a conelike, grayish brown, slightly toughened membrane. (Fig. 4, A.) This breaks very readily in threshing, thereby liberating the enclosed spore masses. If one of the "false" kernels is crushed between the fingers the black smut "dust" will be observed. The kernels are the only part of the head which is transformed into these masses of smut spores. This sorghum smut perpetuates itself from year to year by means of the spores which adhere to the normal sorghum seed. If such contaminated seed is planted without killing the adhering smut spores, the resulting crop will be diseased with the kernel smut.

2. This is the loose kernel smut of sorghum, shown to be botanically different from the ordinary kernel smut. It is not commonly found in Kansas. For the purpose of this bulletin, therefore, they may be treated under one head as the control is the same.

The method of control is by seed treatment. (Pages 31 and 32.) It pays to collect seed from smut-free plants while the plants are still standing in the field. Not only does this enable the grower to select clean seed, but it also gives him the opportunity to select

FIG. 2.—Head smut of sorghum.

typical heads of sorghum. Such seed may be threshed by itself, thereby reducing the chance for contamination.

Head smut of sorghum, *Sorosporium reilianum* McAlp., is very different in appearance from the kernel smut of sorghum in that the entire head is usually destroyed. The glumes and branches of the head, as well as the grain, are transformed into a sooty black mass

FIG. 3.—Kernel smut of sorghum. (A) Normal head of kafir. (B) A head attacked by kernel smut.

of spores (Fig. 2). This condition is noticed as soon as the diseased head emerges from the "boot" of the plant. The black mass is covered with a very thin, whitish membrane which soon ruptures, disappears, and allows the spore mass to be dispersed by the wind and rain. The spores may remain alive in the soil until the following year. If especially susceptible varieties of sorghums, such as Red

FIG. 4.—Kernel smut of sorghums, showing false kernels and normal kernels. (A) False conical shaped bodies containing smut spores. (B) Normal kernels of kafir.

Amber, Freed, and Sumac, are grown on contaminated land, infection occurs in the young seedlings, and smutted plants appear later. In recent years head smut rarely has been found on the varieties of sorghum commonly grown in Kansas.

Rotation of crops, planting varieties of sorghum observed to be free from head smut, and prompt removal and burning of smutted heads will control this disease under Kansas conditions.

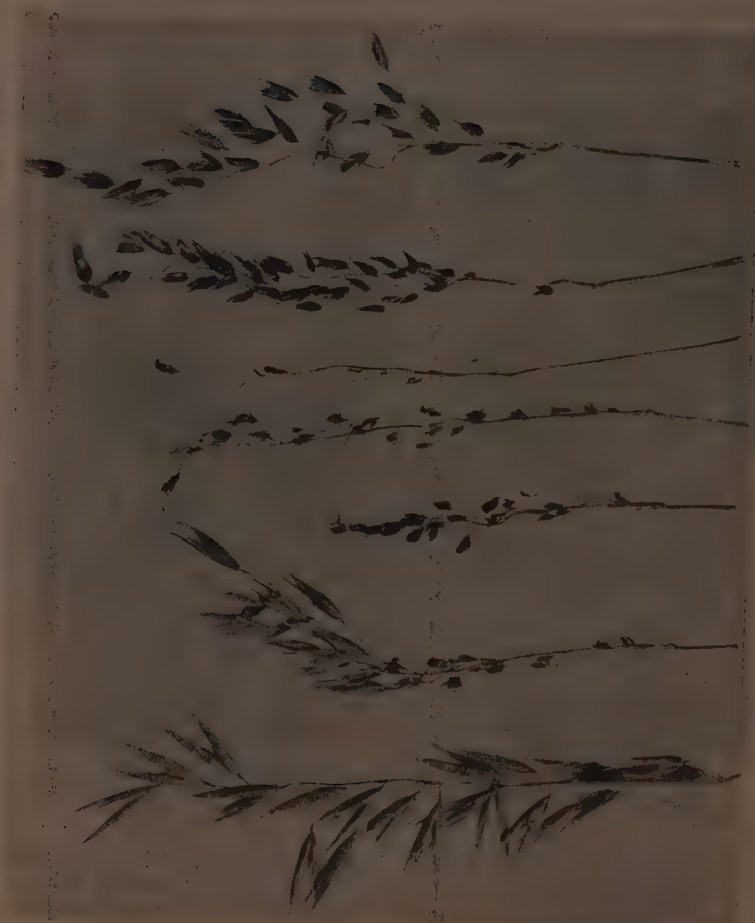

FIG. 5.—Normal, partially smutted, and smutted panicles of oats.

Smuts of Oats

Oat smut, *Ustilago avenae* (Pers.) Rostr., and *Ustilago kolleri* Wille, as found in Kansas, is recognized by the black masses of spores which replace the normal grain. While these two smuts are different species and are slightly different in appearance in the field, they will be treated as one in this discussion since the treatments are identical. *Ustilago avenae* is known as the loose smut, and *U. kolleri* is known as the covered smut. They look very much alike in the field. Oat smut is first noticed as the panicles emerge from the "boots" of the plants (Fig. 5). The grain, and sometimes the chaff, is replaced by this dusty mass, which may later be dispersed, leaving a more or less naked panicle. Generally all the heads of an affected plant are smutted. Diseased plants are often shorter and stand more erect than normal plants. The diseased plants often escape notice, but they may be recognized in the field even before the panicles emerge from the "boot," from the fact that the uppermost leaf of the diseased plant assumes a yellowish or reddish-yellow color.

Certain chemical dust treatments, use of formaldehyde, and growing a resistant variety are means of control. (Pages 25, 31, 33.)

Smuts of Wheat

The stinking smut of wheat, *Tilletia foetida* (Wallr.) Liro and *T. caries* (DC.) Tul., is called covered smut, closed smut, bunt, or stinking smut. The organisms causing the disease are closely related species. In Kansas *T. foetida* is usually the only one present, while in the northwestern part of the United States, *T. caries* is commonly found. In Oregon and Washington the bunt organism lives over in the soil, but in Kansas no difficulty has occurred in this respect. Seed treatment, therefore, under Kansas conditions is a reliable method of control.

The spore masses are enclosed in a brittle, grayish-brown membrane, enlarged or swollen, and commonly called a "smut ball" (Fig. 6). By comparing them with healthy kernels, one finds that they are more nearly spherical, lighter in weight, and generally brownish in external color, with roughened or pitted surfaces. These smut masses are not scattered about by the wind, but are held within the membrane. If this is broken in threshing, however, the spores are scattered; they lodge in the brush and crease of the clean seed, thereby contaminating it.

The disease cannot be recognized by casual examination of the spike or head of wheat alone when the wheat plant begins to head. In general, a bunted head resembles a normal one (Fig. 7). However, diseased heads are darker green when young, and when mature are almost always shorter, with the chaff spreading. Generally all the kernels in a head are attacked, and all the heads in a plant are diseased. Such heads have a foetid odor, not unlike decayed fish; hence the common name, "stinking smut."

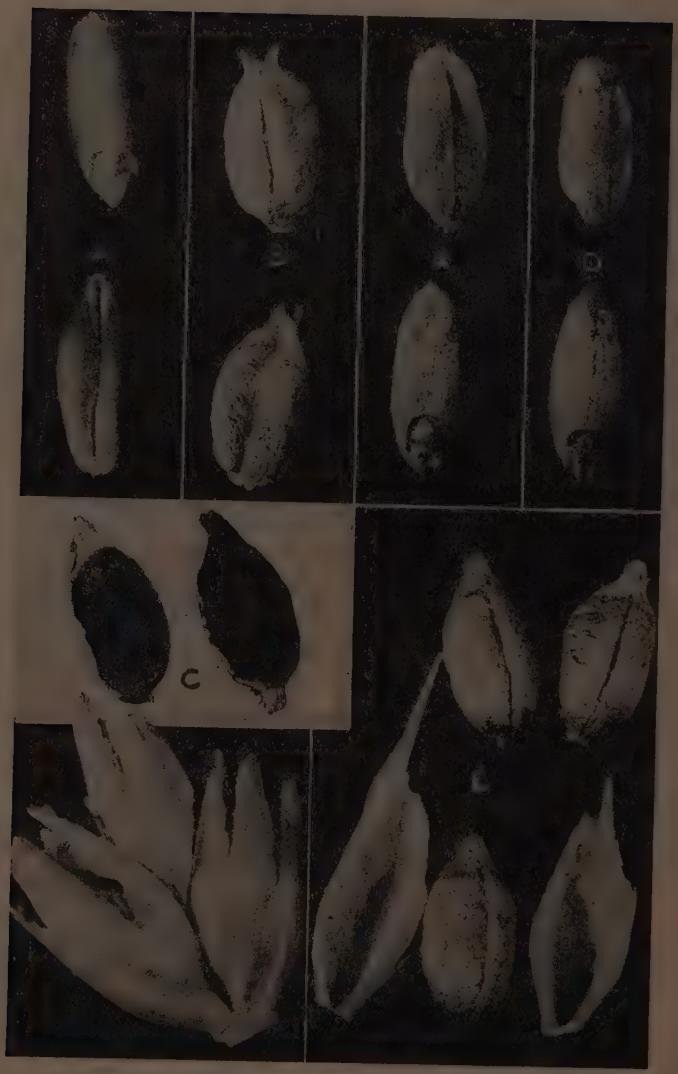

FIG. 6.—(A) Normal kernels of wheat. (B) Smut balls. (C) Smut ball cut in two, showing black mass of smut spores. (D) Wheat kernels in which the "brush" or tip of kernel is covered with smut spores. (E) A wheat spikelet dissected, showing the smut balls hidden within the glumes like wheat kernels.

FIG. 7.—Bunt or stinking smut of wheat. (A) Smutted wheat head; arrows show smut balls hidden within the glumes. (B) Smut balls. (C) Normal kernels of wheat. (D) Normal head of wheat. From general outward appearance it cannot be easily distinguished from the smutted head.

The loss from bunt results not only from the damage to the grain itself, but the foetid odor of the smut is such that a small quantity mixed with grain is sufficient to reduce materially the grade of the wheat, and consequently its market value. Smutted grain cannot be used for flour making unless a special scouring process is used to wash the wheat free of smut.

In some parts of the country serious explosions have occurred in separators and elevators, due at least in part to the presence of this smut dust during threshing and handling of badly smutted crops. Workmen are frequently annoyed by breathing the "black smoke" resulting from threshing a smutted crop.

This disease is controlled by one of the chemical dust treatments or by planting resistant varieties. (Pages 6, 25, 31.)

The loose smut of wheat, *Ustilago tritici* (Pers.) Jens., is first apparent as the heading stage approaches. It is quite different from the stinking smut in that all the glumes or chaff, as well as the kernels, are transformed by the smut fungus into a loose, dusty, black mass of spores (Fig. 8). These masses do not adhere very long to the wheat plant, but are blown away or removed by the rain, leaving only naked wheat stems (rachises). Except for the stem parts, the heads are completely destroyed, and the smut usually attacks every head in a plant. Loose smut has become more common in Kansas in the last 15 years and must be considered a major smut disease of cereals. Up to the last few years there has been no practical method of control, but today new resistant varieties which will overcome this difficulty are being developed and released to farmers. Kawvale is highly resistant, as also is Pawnee, which has been recently developed and released to the wheat industry. The ultimate goal is to breed all hard winter wheat varieties for resistance to loose smut.

The only effective seed treatment for this disease is a special method, known as the modified hot-water treatment. (Page 33.) It is difficult to carry out because the temperature of the water must be regulated very carefully. The modified hot-water treatment cannot be used on a large scale. Small quantities of seed wheat may be treated by this method and this seed used for increase purposes. Even then, very few wheat growers are equipped to use the method satisfactorily.

Flag smut of wheat, *Urocystis tritici* Koern., was first found in northeastern Kansas in 1923. Flag smut has been confined chiefly to Leavenworth and Wyandotte counties, where it occurs mainly on Harvest Queen, although it is found on some other local varieties. This disease has not become serious in northeastern Kansas. Experiments have been conducted with numerous wheat varieties, and it has been found that standard hard winter wheats are resistant to flag smut. Apparently there is little danger that this disease will become a problem in the main hard wheat belt of Kansas.

The disease is easily recognized by the long, narrow stripes of grey or black ruptures on the leaves. Diseased plants are stunted

and generally do not produce heads. The spores fall to the soil or carry over on the threshed seed, and when the seed is sown without treatment the young plants become infected. Seed treatment in itself, however, does not control flag smut, because the organism

FIG. 8.—Loose smut of wheat. Note that the glumes are entirely destroyed by loose smut, which is not the case in bunt.

may live over in the soil from year to year. Care should be exercised to avoid establishing flag smut in soils that are free of it. Such varieties as Kawvale and Clarkan are highly resistant, and it is recommended that one of these be grown if flag smut becomes troublesome in northeastern Kansas.

Smut of Millet

Millet smut, *Ustilago crameri* Körn., may become troublesome in millet-growing communities. It is a "kernel smut," the smut masses being enclosed in a membrane and replacing each kernel separately. When this membrane is broken in threshing, the spores are scattered and cling to the seed.

German millet seed is more frequently contaminated with this smut than are other varieties. It is better to secure seed in a region where smut does not occur. Where there is the possibility of seed contamination, treatment is advisable. The copper carbonate and New Improved Ceresan methods are means of control. (Page 31.)

Smuts of Barley [3]

One of these is a covered smut of barley, *Ustilago hordei* (Pers.) K. & S., the smut masses replacing part of the chaff and the entire grain. A greyish membrane covers the smut mass (Fig. 9, A). This is rather thin and transparent, and shows the greenish-black spore mass contained therein. The spores are not easily scattered by the wind and rain, unless the membrane is broken, which occurs in threshing. The spore masses break up in lumps and the mass is not so powdery as in other smuts. (Fig. 9, B.) Both winter and spring varieties are attacked and no varieties are resistant. New Improved Ceresan treatment is the means of control. (Page 31.)

A second barley smut to be mentioned is a loose smut, specifically named "the brown loose smut." The fungus is deep seated and is carried over inside the seed. The life history is similar to that of loose smut of wheat. The chaff and kernels are replaced by a dark, sooty mass of spores which, viewed in mass, are blackish-brown in color and adhere loosely to the stem of the head (Fig. 10). Because of this, the spore masses are dispersed by the wind and washed away by rain. Before harvest, smutted heads become bare stems. Both winter and spring varieties are attacked.

The modified hot-water treatment is the only method of control for the brown loose smut and the objectionable features of this method have been mentioned. (Pages 33 and 34.) There are no varieties of barley adapted to Kansas that are resistant to this smut; they are all susceptible. The problem of prevention of loss from this disease is a serious one because there is no easy, practical control known. A program of breeding smut-resistant spring and winter barleys adapted to Kansas is under way, and in time satisfactory varieties may be released.

3. The various smuts known to attack barley are similar in appearance. Scientists have distinguished several, but for the purpose of this bulletin they will not all be described separately.

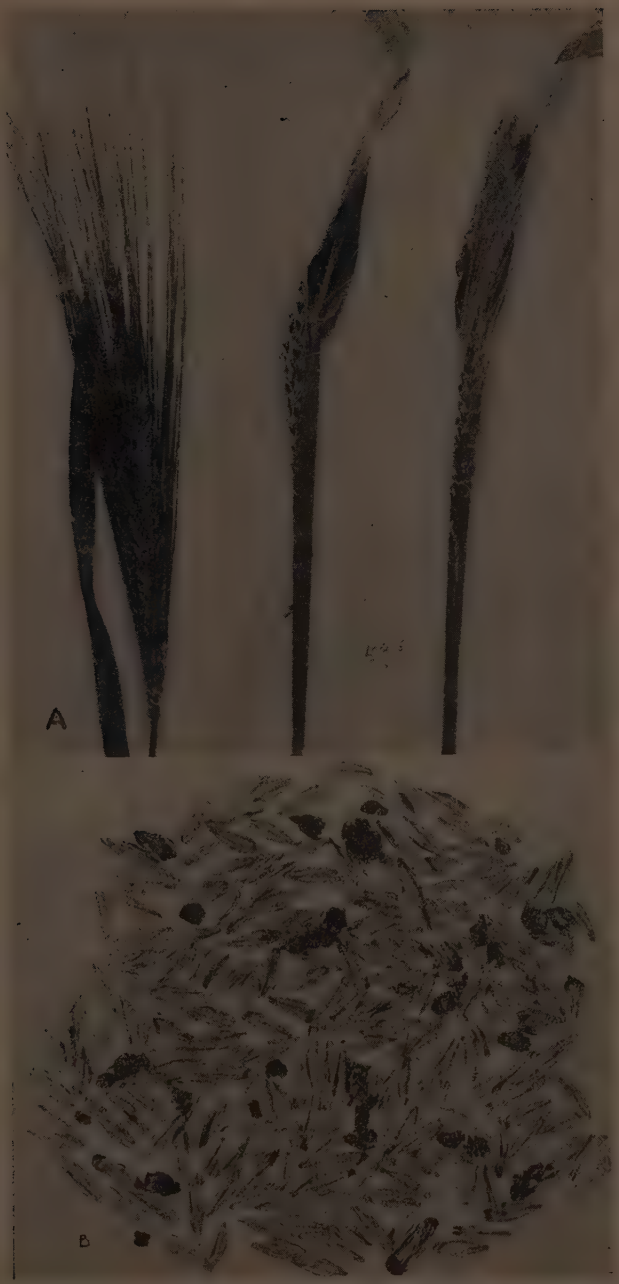

FIG. 9.—Covered smut of barley. (A) Left, normal head. Right, two smutted heads. The beards are underdeveloped and the smut masses are held together by a membrane. (B) A sample of smutted barley. Covered smut of barley breaks up in lumps.

THE CONTROL OF CEREAL SMUTS

Resistant Varieties

In general, two methods may be used to prevent loss from cereal smut diseases: (1) Grow a variety that is not susceptible, or (2) use some specific treatment to kill the smut organism on the seed before planting. The ultimate goal is to produce varieties of wheat, oats,

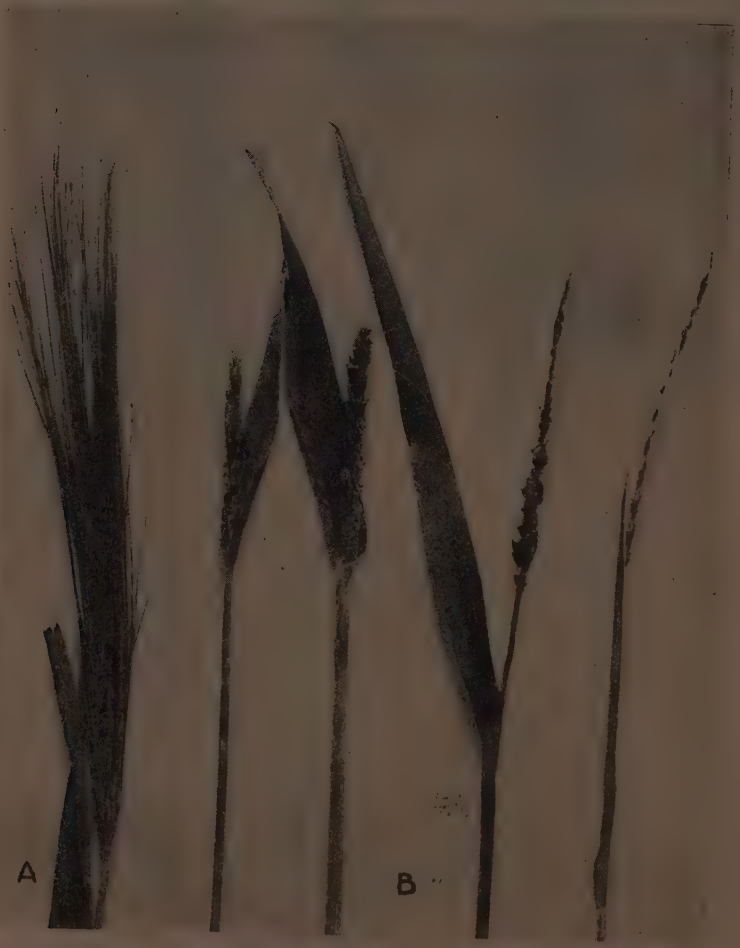

FIG. 10.—Brown loose smut of barley. (A) Normal head of barley. (B) Four heads showing loose smut in various stages of development. The smut masses are easily dispersed by wind and rain.

sorghum, corn, and barley that are resistant, thereby doing away with seed treatments. But many complexities are involved in breeding smut-resistant varieties of crops. It requires many years of experimental work before the goal is reached. The Kansas Agricultural Experiment Station has made distinct progress in obtaining several smut-resistant varieties of wheat and oats. Where resistant varieties can be used, the control of smut or other diseases becomes simple.

Neosho, Osage, Cherokee, Nemaha, and Clinton oats are resistant to oat smut, while Comanche wheat is highly resistant to bunt or stinking smut. Pawnee wheat is moderately resistant to stinking smut and in some areas may not require seed treatment. Pawnee and Kawvale wheats are both highly resistant to the troublesome loose smut. Before long, a good grain type of sorghum should be available that is resistant to sorghum kernel smut.

Seed Treatments

Until additional varieties of cereals are developed that are resistant to the other smuts, seed disinfection or seed treatments are still necessary if losses are to be prevented.

Marked advancement has been made in the last 25 years in new chemical seed treatments. In place of "steeping" or wetting the seed, there are now chemical dusts that are efficient, inexpensive, and easily applied.

With the discovery that certain chemical dusts are good fungicides, seed treatments for grain smuts have become simplified. The application of a dust in place of a solution does away with the wetting and swelling of seed and other objectionable features accompanying wet treatments.

Numerous chemical "dusts" are on the market and the grower is advised to use those products which have given satisfactory control of smuts. Various brands of copper carbonate have been widely and successfully used for the control of certain cereal smuts. Copper carbonate is not recommended for oats and barley smuts; therefore, the grower should follow the specific recommendations made for the smut concerned. Certain chemical dusts, such as ethyl mercury phosphate (New Improved Ceresan), fifty percent tetramethyl thiuramidisulfide (A r a s a n), and tetra-chloro-para-benzoquinone (nonwettable Spergon) have given satisfactory control of certain cereal smuts. At the present time the cost of Arasan and Spergon is high, which is a limiting factor for grain smut control. Some of the advantages of the dust or dry treatments over the formaldehyde wet treatment are as follows:

1. The dust treatments are easily applied and the seed does not become wet or swollen.
2. Seed may be stored after treatment (this depends, however, on the chemical dust in question).
3. Germination of treated seed is not injured if recommendations are carefully followed.

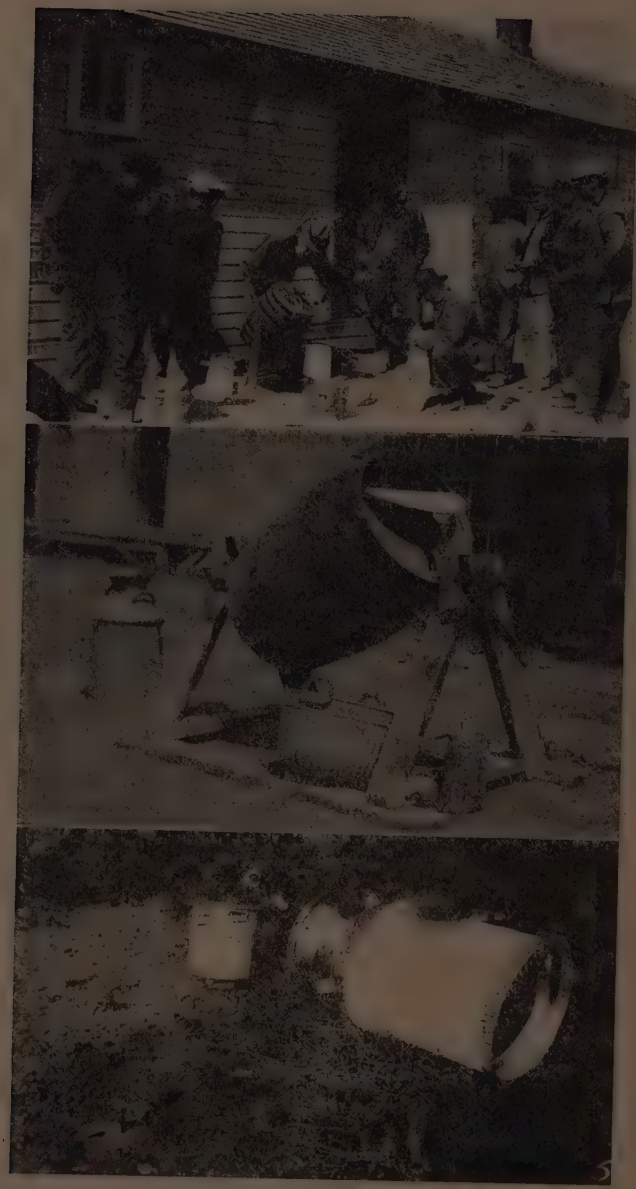

FIG. 11.—Dust treating outfits for smut control. (A) Churn used to treat small seed lots of sorghum. (B) Homemade barrel treater. (C) A milk can is satisfactory for treating sorghum seed.

4. Cost is not excessive.
5. Control of smut is just as effective as that obtained with the wet method.

FIG. 12.—Barrel treaters in use for treating seed wheat with copper carbonate.

6. Treated seed can be planted in either dry or moist soil.
7. Better stands are generally obtained from treated seed than from untreated seed.

In treating seed with the chemical dusts, follow closely the direc-

tions given by the manufacturer of the product being used. Before starting these treatments, be sure to read safety precautions, page 32. Various dust treating machines are on the market, and home-made equipment is found in every community where seed wheat has been treated for smut.

Some of the more common types of treaters used in "dusting" the seed of wheat, oats, barley, and sorghum are illustrated in Figures 11 to 15.

A churn, milk can, or barrel treater is used when small quantities of seed are treated (Figs. 11 and 12).

The Minnesota seed grain treater with New Improved Ceresan is widely used in Kansas. It is simple in construction and inexpensive, and will treat large quantities of seed in a day's time. Very satisfactory results are obtained in smut control where New Improved Ceresan is used. A diagram showing the construction of the treater is shown in Figures 13 and 14. This treater is used to treat seed with New Improved Ceresan.

Large capacity commercial seed cleaners and treaters are occasionally found in some counties. Also, grain elevators frequently have machinery for treating several hundred bushels of seed in a day with these outfits. (Fig. 15.)

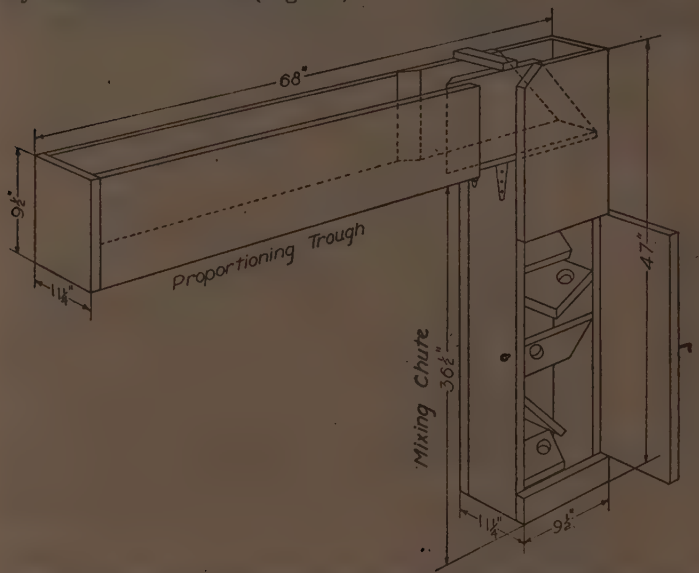

FIG. 13.—View of the Minnesota seed treater to show construction. Directions for construction of this treater may be secured by writing to the Kansas State College Extension Service.

FIG. 14.—The Minnesota seed grain treater, used in applying New Improved Ceresan.

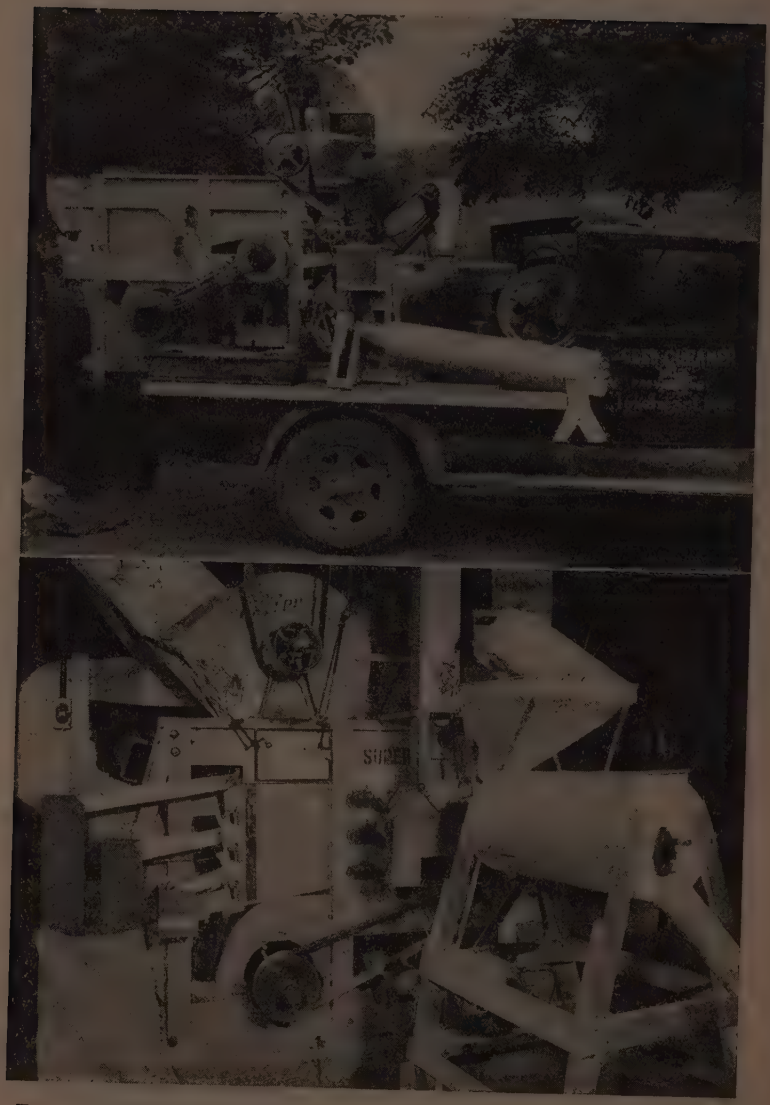

FIG. 15.—Portable and stationary commercial outfits for cleaning and treating wheat seed for stinking smut control.

Copper Carbonate Dust Treatment (for Stinking Smut of Wheat, Kernel Smut of Sorghum, and Millet Smut)

If Coppercarb or copper carbonate dust is used, it is necessary that the seed and chemical dust be thoroughly mixed so that every kernel is completely covered. One of the standard brands should be used at the rate of two ounces to the bushel of seed. The dilute brands (18 to 20 percent) should be used at the rate of three ounces for every bushel of seed. Precautions as to masks and ventilation should be followed. (Page 32.) The seed may be planted immediately, or it may safely be stored in bins until seeding. The seed should be treated in a barrel treater, cement mixer, or any of the large commercial treaters which give satisfactory coating of the seed. The Minnesota seed treater should not be used with copper carbonate. *Shoveling the seed and copper carbonate from one pile to another does not insure sufficient mixing and such a procedure is ineffective.*

New Improved Ceresan Dust Treatment (for Stinking Smut of Wheat, Oat Smut, Covered Smut and Black Loose Smut of Barley, Sorghum Kernel Smut, Millet Smut, and Flax)

New Improved Ceresan (ethyl mercury phosphate) is effective for the control of certain cereal smuts. It has been found unnecessary to mix New Improved Ceresan and the seed as thoroughly as is necessary for copper carbonate. Any type of seed treater is satisfactory, but the Minnesota seed treater is commonly used. Where these outfits are not available, the seed and New Improved Ceresan may be shoveled from one pile to another until well mixed; but quicker and better results are obtained with a seed-treating outfit. Follow the recommendations given on the container for each of the cereal smuts concerned. The treated seed should be *uncovered in a bin, pile, wagonbox, or sacks* for at least 24 to 48 hours before seeding. *In using New Improved Ceresan great care should be taken to follow precisely the directions and precautions given on the container.* This material should be used at the rate of one-half ounce to the bushel of seed. A half-ounce measuring spoon will be found in each container. If a heavier application is used, seed injury will often result.

Treated oats, wheat, and barley seed should not be stored longer than six weeks before seeding. Sorghum, millet and flax seed after treatment should not be stored for more than two weeks before planting because of uncertainty as to the effect on germination. *In using New Improved Ceresan it is essential that the exact quantities of chemical dust and seed are mixed together and that the directions of the manufacturer are followed carefully. Guess work will result in disappointment.* For any further details see the county agricultural agent.

Spergon Dust Treatment (for Sorghum and Flax Seed)

This chemical dust has been found especially useful in the treatment of sorghum and flax seed. Apply Spergon at the rate of two to three ounces per bushel of seed. Mix seed and dust thoroughly, preferably in a rotary seed treater, until the seed is evenly coated. Unless this is done the results will be unsatisfactory.

No special precautions need be followed by workers giving the seed treatment other than those followed in dust-laden atmospheres where dust masks are desirable. Spergon has an advantage over copper carbonate in having a lubricating effect on the seed. It is not injurious to seed germination. It is not effective for the control of oats or barley smuts. While it could be used for bunt control, the present cost is prohibitive.

Flax Seed Treatment

Although flax is not attacked by a smut, the treatment of flax seed with Spergon, New Improved Ceresan, or Arasan has been found desirable, as yields are generally increased. *Follow the directions given by the manufacturer on the container.*

Arasan Dust Treatment (For Sorghum Smut Control and Flax Seed Treatment)

The Arasan dust treatment is similar to the Spergon treatment and has been satisfactory for sorghum kernel smut control. It is not recommended for oats, wheat bunt, or barley smut. In using this chemical follow the instructions of the manufacturer.

General Precautions

Some of the chemical dust treatments, notably the copper carbonate dusts, New Improved Ceresan, and Arasan, cause nausea and irritation to the eyes, nose, and throat of the operators. The treatments should be conducted in the open air, not in a closed room. The operators should avoid breathing the chemical dust. *It is best to wear a dust mask or place a dry cloth (never wet) over the nose and mouth.* This will prevent irritation. This is especially important for persons working for long periods with chemical dust disinfectants.

Do not allow the chemical dusts to accumulate on the skin; wash exposed portions of the body with soap and water.

Sometimes there is a tendency for copper carbonate to cake in the drill when standing overnight. The drill wheels should be rocked back and forth before starting to avoid breaking the working parts. Keep the parts well oiled. The drill should be thoroughly cleaned when seeding is completed.

It is not advisable to feed wheat, oats, barley, or sorghum seed that has been treated with copper carbonate, New Improved Ceresan, or any of the so-called "chemical dusts." The chemical dusts used generally are regarded as poisonous; therefore, *treated seed*

should not be fed to livestock, chickens, or human beings. Follow the same practice that is used in mixing concrete—don't prepare more than is necessary for the job. Treated seed cannot be washed free of the chemical dusts to a degree where it is safe or practical for feeding purposes; therefore, treat only such quantities of seed as are necessary for planting.

Formaldehyde Seed Treatments (for Seed Oats)

The use of formaldehyde (formalin is the commercial name for a 37 to 40 percent solution) for grain smut control is one of the oldest known seed treatments. It has certain disadvantages and limitations as a grain seed treatment when compared to the more simple chemical dusts, but it is still used by some farmers; for this reason it is described sufficiently for those who desire to use it. Formaldehyde should be purchased in sealed containers.

Formaldehyde spray treatment. The so-called spray or dry formaldehyde treatment used for oat smut control consists of mixing 1 pint of full-strength formaldehyde with 1 pint of water, placing the mixture in a quart sprayer. This is sufficient to treat fifty bushels of seed oats and is applied as the seed is being shoveled over from one pile to another. Each scoopful of seed should receive three or four full strokes of the sprayer to insure that the required amount (1 quart) is applied to fifty bushels. Any solution remaining in the sprayer should be sprayed over the surface of the pile of seed oats. The treated seed should stand in a pile for five hours or overnight before planting, being covered with clean sacks, canvas, or blankets to retain the fumes. In case it is not planted immediately, it is necessary to spread out and air the seed for several days before storing. *Seed oats treated by this method is easily injured if stored for longer than three weeks.*

Formaldehyde sprinkle method. While this method is sometimes used for seed oats, it has the disadvantage of wetting the seed. *This method is not recommended for any of the other grain smuts.* The seed oats should be spread out in layers 4 to 6 inches deep on a floor, or a wagonbox may be used. One pint of formaldehyde is mixed with ten gallons of water and applied by means of a garden sprinkling can. The solution should be sprinkled over the entire layer of oats and then shoveled so as to wet the seed, throwing it in a pile. Cover for five hours or over night, after which it should be planted immediately or spread out to dry and sown as soon as possible to prevent seed injury. Treated seed should not be allowed to freeze while wet, nor should it be stored over three weeks.

Modified Hot-water Seed Treatment

This method has been used in a limited way for the control of loose smut of wheat and brown loose smut of barley. It has several objectionable features which make it impracticable. It does not lend itself to use by the average wheat or barley grower. The certi-

fied seed grower may find some use for it. The equipment needed consists of three tanks or vats filled with water, and a well-regulated supply of steam heat to raise the temperature of the water to the proper degree. These containers are spoken of as the soaking, tempering, and treating vats or baths. (Fig. 16.) The essential features of the modified hot water treatment include soaking the seed from four to six hours in cold water, followed immediately by hot water treatment. (The seed should be in burlap sacks not over one-third bushel in a sack. This allows room for the seed to swell.) This is followed by immersion in hot water at 120° F. (tempering bath) for one to two minutes in order to raise the temperature of the sacks and contents before they are placed in the treating bath. If barley seed is being treated, the treatment bath should be carefully regulated at 126° F. and the seed allowed to remain thirteen minutes. If seed wheat is being treated, follow the same procedure except that the treatment bath temperature is 129° F. for ten minutes.

When sacked seed is removed from the hot water, *it should be plunged for several minutes into a vat of cold water;* this will reduce the heat and prevent injury to the seed. Then dump the seed out of the sacks and spread in thin layers to dry. If it is to be hauled back to the farm in sacks, the sacks must *be plunged in cold water to prevent the heat from injuring the germination.*

Where steam is available, as at a creamery, it is easy to heat tanks, vats, or barrels of water to the desired temperature. The larger the volume of water, the easier it becomes to regulate the temperature of the treating bath and to prevent fluctuations. *It is very important to use reliable dairy or floating thermometers and to maintain the specified degree of temperature.*

The Necessity of a Seed Plot

One of the most important features in connection with loose-smut control of wheat and barley is the maintenance of a seed plot. Where wheat or barley is grown on large acreages, it is impossible to treat with the modified hot-water treatment all the seed required for general planting. If a treated seed plot is maintained, it will aid greatly in overcoming the loose-smut ravages.

In starting such a plot one should first carefully select the certified seed, clean by means of fanning, and give it the modified hot-water treatment. This method requires treatment of only a few bushels of seed, and the seed is used as a start in production of seed free from loose smut by planting in a plot by itself. The increase from this may be used for the general crop, a small quantity being reserved for the seed plot.

The selection of a location for the plot is important. The seed plot must not adjoin a field planted with untreated seed of the same crop, as infection will result at flowering time. (Page 10.) It should be located on a piece of land which is large enough to produce twice as much seed as will be required for planting the following year. This will allow for loss in cleaning. The seed plot should be main-

tained every year. Enough seed should be retained to plant the seed plot the following year, the seed being treated regularly until the plot is clean. After this the treatment may be omitted as long as the seed plot is free from loose smut.

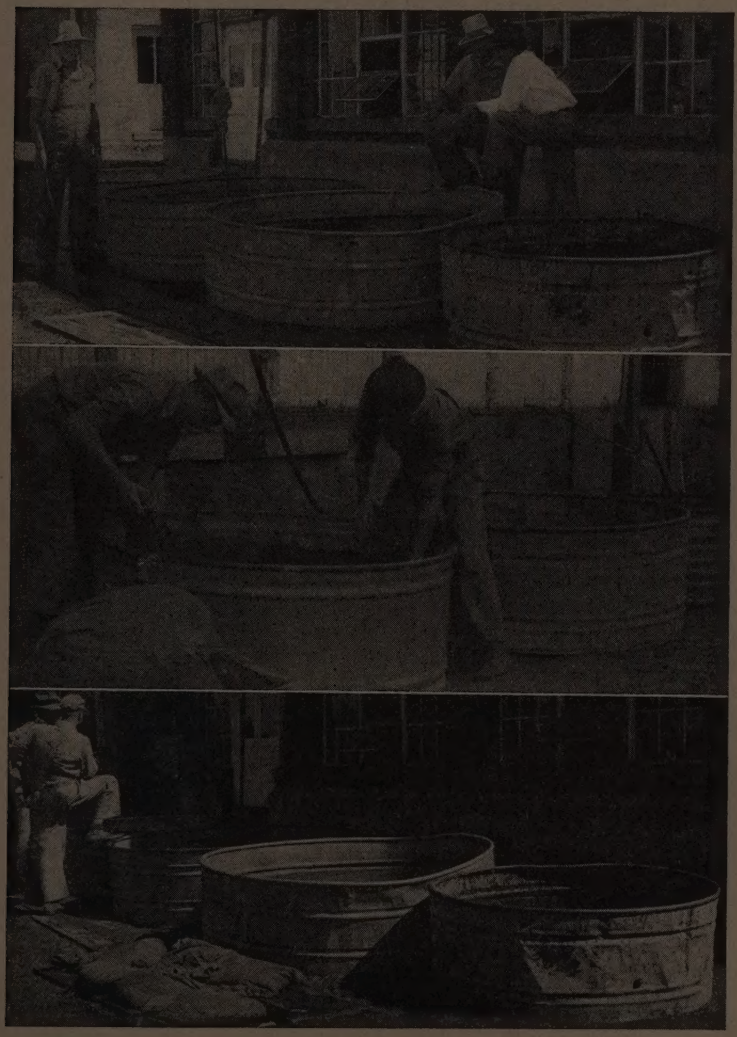

FIG. 16.—Equipment used for the modified hot-water treatment for control of loose smuts of wheat and barley. A creamery furnishes the steam for heating water.

ARE CEREAL AND FORAGE-CROP SMUTS POISONOUS TO LIVESTOCK?

People frequently write to the Kansas Agricultural Experiment Station to learn whether feeding smutty corn, sorghum, barley, oat hay, etc., is injurious or dangerous to livestock. The Kansas Agricultural Experiment Station has conducted experiments to discover what effect feeding large quantities of corn smut and sorghum (kafir and cane) smut has on horses, cows, and calves. The tests show conclusively that these smuts are in no way dangerous or poisonous to such animals. In fact, in the experiments conducted some animals gained weight over a period of time. The only disturbance noted was coughing or sneezing at times because of the dusty smut spores. It should be emphasized that the quantities of smut fed to the animals in these tests were much greater than would be eaten at one time under ordinary field or farm-lot conditions.

No evidence was obtained that feeding smutty oat hay, such as occurred so abundantly in 1936, had any ill effects on livestock.

It should be kept in mind that mouldy hay or fodder does not come under the same heading as grain and forage-crop smuts. It is known that under certain conditions feeding mouldy hay or fodder is decidedly dangerous and injurious.

No experiments have been conducted at the Kansas Agricultural Experiment Station on feeding wheat or barley grain that is badly smutted. As hogs are more sensitive than other animals to mouldy feed, and as no experiments on feeding badly smutted wheat or barley grain to hogs have been conducted at the Kansas Agricultural Experiment Station at Manhattan, the following recent observations are of interest.

In 1935 hogs were fed wheat bunt offal by a farmer at Hays, Kan. The smut came from a mill that had used smutted wheat for milling purposes. The farmer fed large quantities of the smut over an extended period of time; he reported that the smut offal did not injure hogs, but that it was necessary to use additional nutrients or supplements to secure desired gains in weight of animals. In this instance the hogs received much more smut than they would if fed smutted wheat, since little grain was present in the smut offal.

In 1936 limited feeding tests were made by another farmer at Ransom, Kan. He fed badly smutted barley to hogs and a calf over a period of several months. The farmer reported that no injury resulted and that all the animals grew and increased in weight in a normal manner.

Chickens will not be injured by eating smutty grain.

If in doubt, it is always wise first to try feeding one or two animals with questionable feed over a period of time and note the results.

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